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NEW COMPUTERIZED METHOD FOR EVALUATING MARKSMANSHIP FROM WEAPONEER PRINTOUTS

U S ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE

Natick, Massachusetts

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This report describes a new method for analyzing marksmanship using printouts from the Weaponeer, an M-16 shooting simulator. The printout shows where shots hit a target silhouette. A digitizing tablet and a computer program written in BASIC are the foundations for the new method. The tablet is used to record the X and Y locations of each shot and then the program performs a number of different calculations to generate measurements of marksmanship proficiency. Descriptions of the program, associated mathematical concepts, and a listing of the program are included. Keywords: Firing error indicators, Digitizing, Basic software

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Abstract

This report describes a new method for analyzing marksmanship using printouts from the Weaponeer, an M-16 shooting simulator. The printout shows where shots hit a target silhouette. A digitizing tablet and a computer program written in BASIC are the foundations for the new method. The tablet is used to record the X and Y locations of each shot and then the program performs a number of different calculations to generate measurements of marksmanship proficiency. Descriptions of the program, associated mathematical concepts, and a listing of the Microsoft program are included.

Introduction

Marksmanship proficiency is an important basic skill required of all soldiers in the U.S. Army. The availability of firing ranges, safety and environmental concerns, as well as the cost of live ammunition have all limited the amount of hands-on training some soldiers receive. To help solve these problems, the Weaponeer (Spartanics, Ltd., Rolling Meadows, Il.), an M-16 rifle marksmanship simulator, was developed.

The Weaponeer is a self-contained simulator that can be used for training and analysis of marksmanship. It consists of a non-restorable M16A1 rifle adapted with a target sensor, scaled targets equipped with light-emitting diodes, and a control console that regulates all Weaponeer functions. The video display on the control console allows a trainer to watch the aiming pattern and shot location as a person is being tested. The replay option allows the person shooting to also see their aiming pattern and shot location. The twenty-five meter zeroing target, as well as the 100m and 250m targets can be controlled by the console. A printer in the console allows hard copies of each session to be made. The hard copies include a listing of the number of shots, hits, misses, and late shots (if the timer is used); and a display of the target with hits marked. The weaponeer is equipped with a recoil rod that attaches to the end of the rifle to simulate firing of a real weapon. In addition, because of the replay and tracking functions, the Weaponeer can be used to isolate problems in a soldier's shooting mechanics (Martin, 1987).

Marksmanship proficiency has been evaluated primarily in a hit or miss fashion. Schendel, Heller, Finley, and Hawley (1985) evaluated marksmanship on the basis of the number of hits or misses on various targets. Johnson and Kobrick (1988) and Kobrick, Johnson, and McMenemy (1988) evaluated marksmanship on the number of shots that fit within a 1x1 and 2x2 Weaponeer printout grid (3/16"x3/16" and 3/8"x3/8" respectively) of the simulated 25 meter zeroing target as well as hits and misses on the simulated 100 and 250 meter pop-up targets.

The purpose of this paper is to describe a new method of evaluating marksmanship performance by digitizing the paper printouts of one's shooting session. This method is advantageous because it provides a more precise description of a soldier's shooting performance. The digitizing method uses as its basis a continuous numbering system whereas the previous methods are discrete in nature.

Methods

Hardware Description

Printouts from the Weaponeer were analyzed using two different hardware/software configurations.

The first used two sheets of plexi-glass taped together to form a sandwich to stabilize the Weaponeer printouts. The sandwich was then placed on top of a digitizing table (model AC40, Altek Corporation, Silver Spring, MD) with 1/100mm resolution. The digitizer was interfaced with a microcomputer (model 310, Hewlett Packard, Lexington, MA). A hard disk drive, 3 1/2 inch floppy disk drive, and Think Jet printer, all from Hewlett Packard, were attached for software operation, data storage, and hard copy output.

The other method used the Sigma-Scan software package (version 3.90) and a 12x12 inch digitizing tablet (Jandel Scientific, Corte Madera, CA), a Zenith Z-180 lap-top personal computer with hard and floppy disk drives to collect and store data. Two transparancies were taped together to form a sandwich to keep the Weaponeer printouts in place while data was being collected.

Software Description

Three different versions of the program were written. One was for use with the Altek tablet and used Hewlett Packard (HP) Basic 3.0 and the other two were written for use with Microsoft Basic 6.0 to process the data collected with the Jandel tablet. The two versions differ in the measures used to evaluate marksmanship. One evaluated marksmanship in the same manner as the HP program while the other produced some different measures.

The HP program and one of the Microsoft programs used the following measures to evaluate marksmanship:

- Average distance from the centroid of the silhouette
- Standard deviation of the shot distances as a measure of shot group tightness
- Horizontal and vertical shot group tightness (as defined in the mathematical concepts section)
- The coordinates of the center of mass and the average X and Y value which could be used together to describe the location of the shot group

The other Microsoft program used the following measures to evaluate marksmanship in a slightly different manner:

- Average distance from the centroid of the silhouette
- Area of the shot group as a measure of shot group tightness (as described in the mathematical concepts section)
- Horizontal and vertical shot group tightness (same as above)
- Horizontal and vertical range (as described in the mathematical concepts section)
- Horizontal and vertical deviations (as described in the mathematical concepts section)

Once the data points have been obtained for the above measures, they are transferred to a VAX780 (Digital Computations, Maynard, MA) for statistical analysis of marksmanship proficiency.

Operation of Software

This section is split up into two different parts. The first for the operation of the HP program used with the Altek digitizing table and the other section for the Microsoft programs.

HP program

A listing of the prompts given and the appropriate responses is found in Appendix 1.

Upon loading the program and running it, the user is given the option of creating an ASCII file to store the data (An ASCII file is necessary to transfer the data to the VAX computer for statistical analysis). It is noted that a new data file should be started only if beginning a new project, otherwise the data will be added to the existing file. In the event that the user chooses to create a new data file, instructions are given as to where to edit the program to change the data file name.

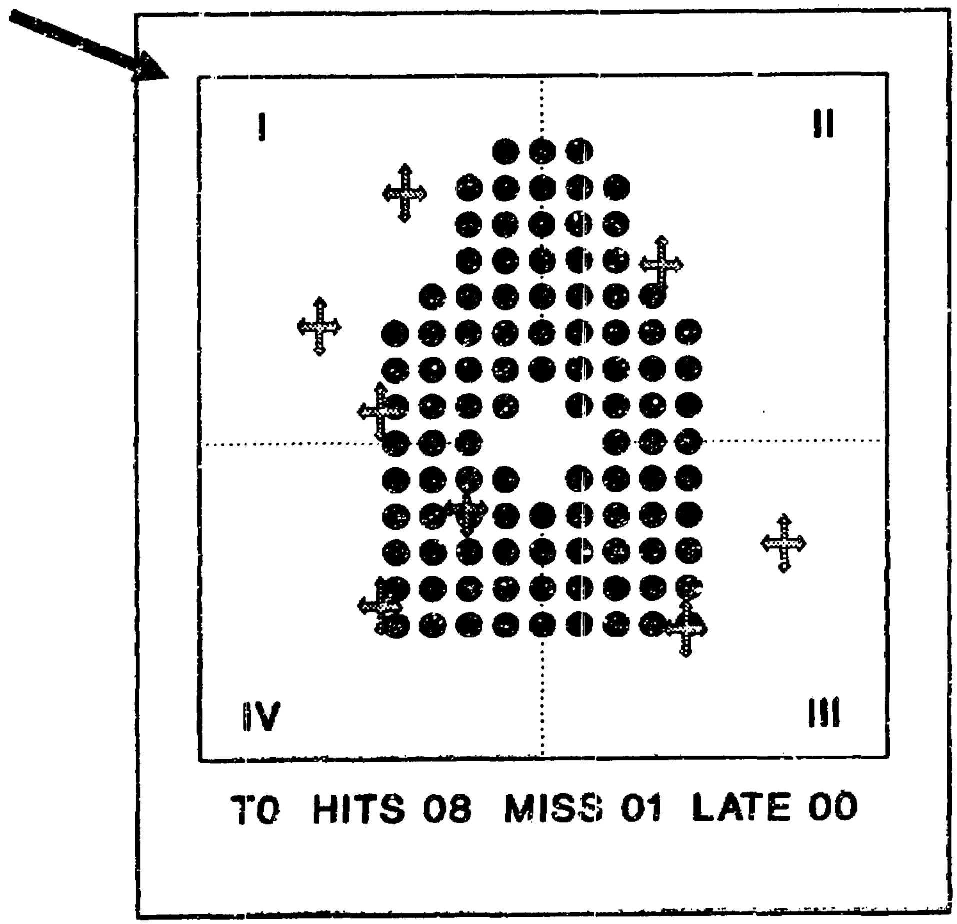
The user is prompted to input the subject number, name and the trial number. The program is designed to run on a four test condition, two trial system with each test having 9 shots to be digitized. With slight modifications, the program can be adapted for different variations in test conditions, trials and shots per trial. The program pauses while the user reads directions on how to proceed. Once the program is continued, the user digitizes the lower left and right hand corners of the printout to establish chart horizontal axis. The chart horizontal axis is established because the Weaponeer printout must be lined up with the table's horizontal axes. The program contains a procedure which compensates for any discrepancy between the printout's and the table's horizontal axes. The user then digitizes the same two points again to calculate the coordinates of the center of mass of the target. The reasons for this are explained in the mathematical concepts section. The user proceeds with digitizing the 9 shots. In the event there were missed shots (ie. off the printout), the outer corner of the quadrant in which the greatest number of shots occurred is digitized for each missed shot. (See Figure 1) The outer corner is chosen arbitrarily as the farthest point from the center of mass. After the nine shots are digitized, the user returns to the instructions for alignment and center of mass calculation and continues as mentioned above. After the fourth test, the user is asked again for the trial number and continues in the same manner as above from that point. The program is set up to accept two trials for each subject and after the second trial data is processed, the computer prompts the user for the next subject's number. At this point, the user

can proceed or end the session by exiting the program.

Microsoft Programs

The two Microsoft programs operate in a slightly different manner than the HP program. Using the Sigma-Scan software and the Jandel tablet, the user begins by digitizing the upper left, lower left and right hand corners of the printouts to align the printout with the tablet's horizontal axis and to calculate the center of mass of the target. The operator may proceed with digitizing the nine shots. This is repeated until all data has been collected. One cautionary note is that the user must make sure to analyze the printouts in the same order for each subject and always digitize the three indicated corners first. Once all the data has been collected, it is saved in ASCII format and then transferred to the directory of the computer that contains the Microsoft Basic program (This can be done using the Sigma-Scan software). The user then runs the Basic program to obtain the marksmanship measures from the digitized data.

Figure 1: Weaponeer Printout Example



How To Handle Missed Shots

Since most of the 8 shots appear in quadrant I, the arrow indicates which corner should be digitized for the 9th shot

Mathematical Concepts

This section provides a short explanation of the formulas used in the software, especially those that pertain to the use of the digitizer.

Note: When the Altek digitizing tablet and the HP program are used, the X and Y coordinates from the tablet are divided by 100 so that all distances are calculated in millimeters. When the Jandel tablet and the Microsoft program are used, a screen unit conversion factor is used to convert all distances to millimeters. Due to human error in using the tablets, all results are accurate within 1 mm of the calculated value.

Shot Distances

The programs are designed to calculate the X and Y coordinates of the centroid of the target and to accept the coordinates of each shot. By using the differences between the coordinates of the centroid and those of each shot, and then applying the Pythagorean Theorem to those differences, the distances of each shot from the centroid is easily calculated.

Horizontal and Vertical Shot Group Tightness

As mentioned earlier, shot group tightness is broken down into X and Y measures. The horizontal and vertical shot group tightness is little more than a Z-score x 2. The average X and Y value of the shot group is calculated as well as the standard deviation of the X coordinates and Y coordinates. The measure of shot group tightness is then calculated as follows:

Horizontal Shot Group Tightness$=2 \cdot SD_x$

Vertical Shot Group Tightness$=2 \cdot SD_y$

Overall Shot Group Tightness

The overall shot group tightness is measured as the standard deviation of the shot distances. (This measure is used in the HP program and in one of the Microsoft programs)

Horizontal and Vertical Range

The horizontal range is the distance between the two shots farthest apart in the X direction and the vertical range is the distance between the two shots farthest apart in the Y direction.

Horizontal and Vertical Deviation Relative to the Target Centroid

The horizontal and vertical deviations utilize the coordinates of each shot and the coordinates of the target centroid to find an average location of the shot group relative to the centroid as follows:

$$\text{Horizontal Deviation} = \Sigma(S_x - C_x)/9$$
$$\text{Vertical Deviation} = \Sigma(S_y - C_y)/9$$

Where: S_x = Shot X-coordinate
S_y = Shot Y-coordinate
C_x = Centroid X-coordinate
C_y = Centroid Y-coordinate

Area

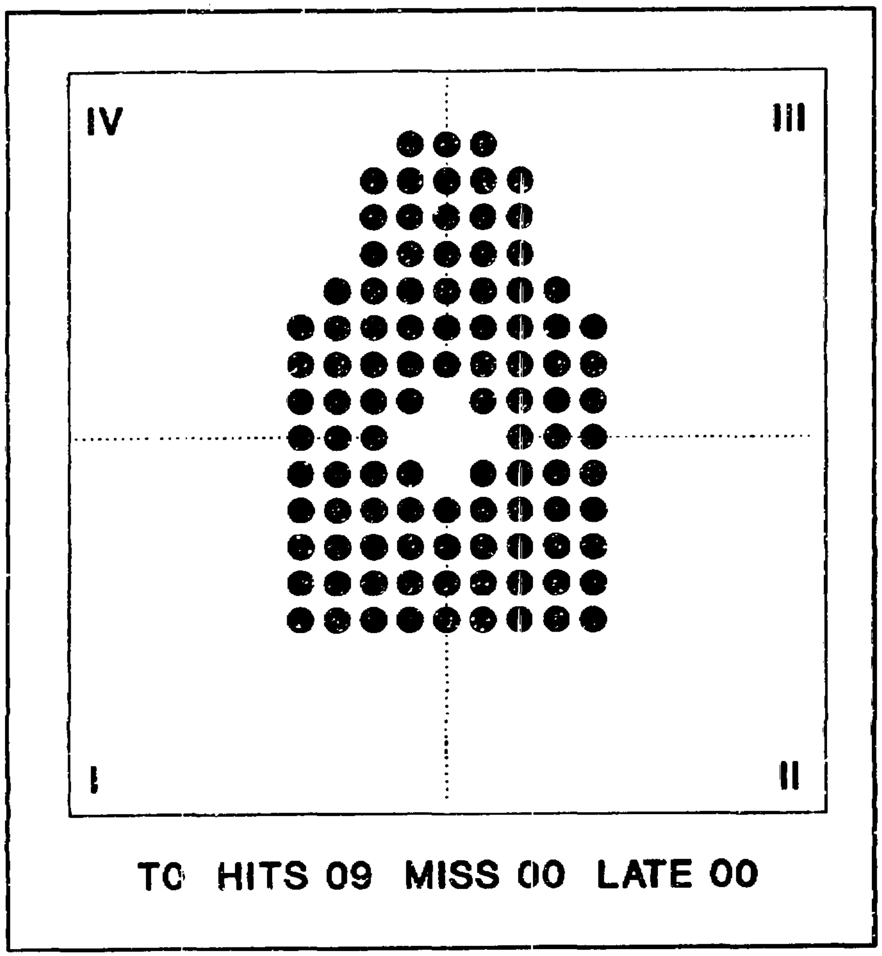
The area is the product of the horizontal and vertical ranges.

Area=Horizontal Range x Vertical Range

Calculating the Centroid of the Target

Due to the fact that there is no distinct point to digitize for the centroid as a result of the way the Weaponeer produces its printouts, the calculation of the coordinates of the centroid of the target is performed as follows. The x coordinate is determined by taking the difference between the x coordinates of the lower left and right hand corners of the Weaponeer printout, dividing the difference by two and adding this result to the x coordinate of the lower left hand corner. The y coordinate of the centroid is calculated by taking the difference between the upper left and lower left corners of the printout then multiplying this difference by 8/18 (the centroid is not in the middle of the printout in the vertical direction) and adding this number to the lower left y coordinate. (Either lower y coordinate could be used because the alignment procedure makes them both the same.) See Figure 2 for a diagram indicating which corners are referenced.

Figure 2: Weaponeer Printout Example



Where to digitize for centroid

The corners labeled I, II and IV are the ones used to calculate the centroid

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Martin, Peter. Free Fire. Soldiers. 1987;42:6-9.

Schendel, J.D., Heller, F.H., Finley, D.L., Hawley, J.K. Use of Weaponeer Marksmanship Trainer in Predicting M16A1 Rifle Qualification Performance. Human Factors. 1985;27(3):313-325.

Appendix 1

Hewlett Packard Program Prompts and Responses

PROMPT "Do you want to create an ASCII file?"

(Enter 1 only if starting a new project or 2 if continuing)

If starting a new project push the stop button and edit lines 780, 820, and 1010 to change the name of the file you want to save the data in

******************** CAUTION ***********************

If you do not change the file name, you run the risk of writing over old data

REPLY press 2 if finishing digitizing printouts that you have started previously but press 1 if you want to start new data. As the caution notes, you may write over old data if you do not change the file name that it is stored under.

PROMPT "What is the subject's number"
"What is the subject's name?"
"What is the trial number?"
"If you want to end this session, enter 0"

REPLY answer the first two questions appropriately. In the case of the trial number, entering zero will allow you to exit the program, otherwise enter the trial number.

Appendix 2

Microsoft Program Listing

The following is the Microsoft program currently used to process data.

```
10 DECLARE SUB sdpts(xar!(), yar!(), avx!(), avy!(), sdxpts!(),
   sdypts!())
20 DECLARE SUB avpts(xar!(), yar!(), avx!(),avy!())
30 DECLARE SUB ranges(avx!(), avy!(), sdxpts!(), sdypts!(),
   hsgt!(), vsgt!())
40 DECLARE SUB fop(fad!(), area!(), hdev!(), vdev!(), xrng!(),
   yrng!(), hsgt!(), vsgt!())
50 DECLARE SUB readin(xar!(), yar!())
60 DECLARE SUB align(xar!(), yar!())
70 DECLARE SUB center(xar!(), yar!(), xcm!(), ycm!())
80 DECLARE SUB distance(xar!(), yar!(), xcm!(), ycm!(), dist!(),
   fad!())
90 DECLARE SUB rngarea(xar!(), yar!(), xrng!(), yrng!(), area!())
100 DECLARE SUB deviations(xar!(), yar!(), xcm!(), ycm!(),
    hdev!(), vdev!())
110 DIM xar(1 TO 16, 1 TO 2, 1 TO 4, 1 TO 12), yar(1 TO 16,
    1 TO 2, 1 TO 4, 1 TO 12)
120 DIM fad(1 TO 16, 1 TO 2, 1 TO 4), dist(1 TO 16, 1 TO 2,
    1 TO 4, 4 TO 12)
130 DIM xcm(1 TO 16, 1 TO 2, 1 TO 4), ycm(1 TO 16, 1 TO 2,
    1 TO 4)
140 DIM xrng(1 TO 16, 1 TO 2, 1 TO 4), yrng(1 TO 16, 1 TO 2,
    1 TO 4)
150 DIM area(1 TO 16, 1 TO 2, 1 TO 4)
160 DIM hdev(1 TO 16, 1 TO 2, 1 TO 4), vdev(1 TO 16, 1 TO 2,
    1 TO 4)
170 DIM sdxpts(1 TO 16, 1 TO 2, 1 TO 4), sdypts(1 TO 16, 1 TO 2,
    1 TO 4)
180 DIM hsgt(1 TO 16, 1 TO 2, 1 TO 4), vsgt(1 TO 16, 1 TO 2,
    1 TO 4)
190 DIM avx(1 TO 16, 1 TO 2, 1 TO 4), avy(1 TO 16, 1 TO 2,
    1 TO 4)
200 CALL readin(xar(), yar())
210 CALL align(xar(), yar())
220 CALL center(xar(), yar(), xcm(), ycm())
230 CALL distance(xar(), yar(), xcm(), ycm(), dist(), fad())
240 CALL rngarea(xar(), yar(), xrng(), yrng(), area())
250 CALL deviations(xar(), yar(), xcm(), ycm(), hdev(), vdev())
260 CALL avpts(xar(), yar(), avx(), avy())
270 CALL sdpts(xar(), yar(), avx(), avy(), sdxpts(), sdypts())
```

```
280 CALL ranges(avx(), avy(), sdxpts(), sdypts(), hsgt(), vsgt())
290 CALL fop(fad(), area(), hdev(), vdev(), xrng(), yrng(),
    hsgt(), vsgt())
300 END

310 SUB align(xar(), yar())
320 DIM factor(1 TO 16, 1 TO 2, 1 TO 4), real
330 CLS
340 FOR a = 1 TO 16
350 FOR b = 1 TO 2
360 FOR c = 1 TO 4
370 factor(a, b, c) = ABS(yar(a, b, c, 1) - yar(a, b, c, 2))
380 FOR g = 4 TO 12
390 yar(a, b, c, g) = yar(a, b, c, g) - factor(a, b, c)
400 NEXT g
410 IF yar(a, b, c, 1) > yar(a, b, c, 2) THEN yar(a, b, c, 1) =
    (yar(a, b, c, 1) - factor(a, b, c))
420 IF yar(a, b, c, 2) > yar(a, b, c, 1) THEN yar(a, b, c, 2) =
    (yar(a, b, c, 2) - factor(a, b, c))
430 NEXT c
440 NEXT b
450 NEXT a
460 END SUB

470 SUB avpts(xar(), yar(), avx(), avy())
480 DIM sumxpts(1 TO 16, 1 TO 2, 1 TO 4), sumypts(1 TO 16,
    1 TO 2, 1 TO 4), real
490 FOR a = 1 TO 16
500 FOR b = 1 TO 2
510 FOR c = 1 TO 4
520 FOR d = 4 TO 12
530 sumxpts(a, b, c) = sumxpts(a, b, c) + xar(a, b, c, d)
540 sumypts(a, b, c) = sumypts(a, b, c) + yar(a, b, c, d)
550 NEXT d
560 avx(a, b, c) = sumxpts(a, b, c) / 9
570 avy(a, b, c) = sumypts(a, b, c) / 9
580 NEXT c
590 NEXT b
600 NEXT a
610 END SUB

620 SUB center(xar(), yar(), xcm(), ycm())
630 FOR n = 1 TO 16
640 FOR o = 1 TO 2
650 FOR p = 1 TO 4
660 xcm(n, o, p) = xar(n, o, p, 1) + ((ABS(xar(n, o, p, 1) -
    xar(n, o, p, 2)) / 2))
```

```
670 ycm(n, o, p) = (yar(n, o, p, 3) - yar(n, o, p, 1)) * (8/16) +
    yar(n, o, p, 1)
680 NEXT p
690 NEXT o
700 NEXT n
710 END SUB

720 SUB deviations(xar(), yar(), xcm(), ycm(), hdev(), vdev())
730 DIM sumx(1 TO 16, 1 TO 2, 1 TO 4), sumy(1 TO 16, 1 TO 2,
    1 TO 4)
740 FOR a = 1 TO 16
750 FOR b = 1 TO 2
760 FOR c = 1 TO 4
770 FOR d = 4 TO 12
780 sumx(a, b, c) = sumx(a, b, c) + (xar(a, b, c, d) -
    xcm(a, b, c)) / 3.442
790 sumy(a, b, c) = sumy(a, b, c) + (yar(a, b, c, d) -
    ycm(a, b, c)) / 3.442
800 NEXT d
810 hdev(a, b, c) = sumx(a, b, c) / 9
820 hdev(a, b, c) = hdev(a, b, c) * 3.57
830 vdev(a, b, c) = sumy(a, b, c) / 9
840 vdev(a, b, c) = vdev(a, b, c) * 3.57
850 NEXT c
860 NEXT b
870 NEXT a
880 END SUB

890 SUB distance (xar(), yar(), xcm(), ycm(), dist(), fad())
900 DIM sumd(1 TO 16, 1 TO 2, 1 TO 4)
910 FOR a = 1 TO 16
920 FOR b = 1 TO 2
930 FOR c = 1 TO 4
940 FOR d = 4 TO 12
950 dist(a, b, c, d) = (ABS(xar(a, b, c, d) - xcm(a, b, c)) ^ 2)
960 dist(a, b, c, d) = dist(a, b, c, d) + (ABS(yar(a, b, c, d) -
     ycm(a, b, c)) ^ 2)
970 dist(a, b, c, d) = SQR(dist(a, b, c, d))
980 dist(a, b, c, d) = dist(a, b, c, d) / 3.442
990 dist(a, b, c, d) = dist(a, b, c, d) * 3.57
1000 sumd(a, b, c) = sumd(a, b, c) + dist(a, b, c, d)
1010 NEXT d
1020 fad(a, b, c) = sumd(a, b, c) / 9
1030 NEXT c
1040 NEXT b
1050 NEXT a
1060 END SUB
```

```
1070 SUB fop (fad(), area(), hdev(), vdev(), xrng(), yrng(),
     hsgt(), vsgt())
1080 OPEN "newdat" FOR OUTPUT AS #2
1090 FOR a = 1 TO 16
1100 PRINT "subn    avdis    area    hdev     vdev     xrng
     yrng     hsgt     vsgt"
1110 FOR b = 1 TO 2
1120 FOR c = 1 TO 4
1130 WRITE #2, fad(a, b, c), area(a, b, c), hdev(a, b, c),
     vdev(a, b, c), xrng(a, b, c), yrng(a, b, c), hsgt(a, b, c),
     vsgt(a, b, c)
1140 PRINT USING "##   ###.##   #####.##   ###.##   ###.##
     ###.##   ###.##   ###.##   ###.##"; a, fad(a, b, c),
     area(a, b, c), hdev(a, b, c), vdev(a, b, c),  xrng(a, b, c),
     yrng(a, b, c), hsgt(a, b, c), vsgt(a, b, c)
1150 NEXT c
1160 NEXT b
1170 NEXT a
1180 END SUB

1190 SUB ranges (avx(), avy(), sdxpts(), sdypts(), hsgt(),
   vsgt())
1200 FOR a = 1 TO 16
1210 FOR b = 1 TO 2
1220 FOR c = 1 TO 4
1230 hsgt(a, b, c) = (avx(a, b, c) + sdxpts(a, b, c)) -
      (avx(a, b, c) - sdxpts(a, b, c))
1240 hsgt(a, b, c) = hsgt(a, b, c) / 3.442
1250 hsgt(a, b, c) = hsgt(a, b, c) * 3.57
1260 vsgt(a, b, c) = (avy(a, b, c) + sdypts(a, b, c)) -
      (avy(a, b, c) - sdypts(a, b, c))
1270 vsgt(a, b, c) = vsgt(a, b, c) / 3.442
1280 vsgt(a, b, c) = vsgt(a, b, c) * 3.57
1290 NEXT c
1300 NEXT b
1310 NEXT a
1320 END SUB

1330 SUB readin (xar(), yar())
1340 OPEN "DTFL6.PRN" FOR INPUT AS #1
1350 subn = 1
1360 trln = 1
1370 tstn = 1
1380 shtn = 1
1390 DO UNTIL EOF(1)
1400 INPUT #1, x, y
```

```
1410 IF trln > 2 THEN trln = 1
1420 IF tstn > 4 THEN tstn = 1
1430 IF shtn > 12 THEN shtn = 1
1440 xar(subn, trln, tstn, shtn) = x
1450 yar(subn, trln, tstn, shtn) = y
1460 IF trln = 2 AND tstn = 4 AND shtn = 12 THEN subn = subn + 1
1470 IF tstn = 4 AND shtn = 12 THEN trln = trln + 1
1480 IF shtn =12 THEN tstn = tstn + 1
1490 shtn = shtn + 1
1500 LOOP
1510 CLOSE #1
1520 END SUB

1530 SUB rngarea (xar(), yar(), xrng(), yrng(), area())
1540 DIM bigx(1 TO 16, 1 TO 2, 1 TO 4), bigy(1 TO 16, 1 TO 2,
     1 TO 4)
1550 DIM smallx(1 TO 16, 1 TO 2, 1 TO 4), smally(1 TO 16, 1 TO 2,
     1 TO 4)
1560 FOR a = 1 TO 16
1570 FOR b = 1 TO 2
1580 FOR c = 1 TO 4
1590 FOR d = 4 TO 12
1600 smallx(a, b, c) = xar(a, b, c, 4)
1610 smally(a, b, c) = yar(a, b, c, 4)
1620 IF xar(a, b, c, d) > bigx(a, b, c) THEN
1630 bigx(a, b, c) = xar(a, b, c, d)
1640 END IF
1650 IF yar(a, b, c, d) > bigy(a, b, c) THEN
1660 bigy(a, b, c) = yar(a, b, c, d)
1670 END IF
1680 IF xar(a, b, c, d) < smallx(a, b, c) THEN
1690 smallx(a, b, c) = xar(a, b, c, d)
1700 END IF
1710 IF yar(a, b, c, d) < smally(a, b, c) THEN
1720 smally(a, b, c) = yar(a, b, c, d)
1730 END IF
1740 NEXT d
1750 xrng(a, b, c) = (bigx(a, b, c) - smallx(a, b, c)) / 3.442
1760 xrng(a, b, c) = xrng(a, b, c) * 3.57
1770 yrng(a, b, c) = (bigy(a, b, c)-smally(a, b, c)) / 3.442
1780 yrng(a, b, c) = yrng(a, b, c) * 3.57
1790 area(a, b, c) = xrng(a, b, c) * yrng(a, b, c)\
1800 NEXT c
1810 NEXT b
1820 NEXT a
1830 END SUB
```

```
1840 SUB sdpts (xar(), yar(), avx(), avy(), sdxpts(), sdypts())
1850 DIM sumxpts(1 TO 16, 1 TO 2, 1 TO 4), sumypts(1 TO 16,
     1 TO 2, 1 TO 4), real
1860 FOR a = 1 TO 16
1870 FOR b = 1 TO 2
1880 FOR c = 1 TO 4
1890 FOR d = 4 TO 12
1900 sumxpts(a, b, c) = sumxpts(a, b, c) + (xar(a, b, c, d) -
     avx(a, b, c)) ^ 2
1910 sumypts(a, b, c) = sumypts(a, b, c) + (yar(a, b, c, d) -
     avy(a, b, c)) ^ 2
1920 NEXT d
1930 sdxpts(a, b, c) = SQR(sumxpts(a, b, c) / 9)
1940 sdypts(a, b, c) = SQR(sumypts(a, b, c) / 9)
1950 NEXT c
1960 NEXT b
1970 NEXT a
1980
END SUB
```

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